by Rodger J. Ross

DISTORTION IN MOTION PICTURE SOUND TRACKS

Until magnetic recording was introduced after World War II, sound was recorded as a continuous photographic track on the edge of the picture film, in the form of either variable density or variable area. These methods were known at first as optical sound recording, and the term is still widely used. But later on, the term "photographic" was adopted in industry standards and recommended practices.

The first Movietone newsreel was shown to the public in 1927, and the first talking picture made outdoors, **In Old Arizona**, was released in December 1928, nearly 50 years ago. Sound recording for these releases utilized a light source that varied in intensity to expose the film. The development of light-modulating devices, galvanometers and light valves, led very quickly to the adoption of sound on film in motion picture production. But the early recordings suffered from considerable amounts of distortion.

Investigations of variable density recording showed that unwanted signals were being generated in a non-linear transfer characteristic when low level, high frequency components were superimposed on high level, lower frequencies. A method of intermodulation testing was devised consisting of a 1 kHz or 7 kHz signal imposed on a 60 Hz tone at 10dB lower level, recorded on film at various exposure levels, development gammas and printer exposures. Conditions giving the lowest value of 60 Hz output were then selected as most favorable for production recording. In practice the intermodulation component could be reduced to about 5 percent of the fully recorded signal, corresponding to approximately 1 percent harmonic distortion.

Early variable area tracks suffered from severe sibilance, caused by rectification of the signal by fill-in of the recorded audio waveforms, producing harmonic distortion. A technique known as cross modulation analysis was developed, in which a series of recordings were made of a 9 kHz tone modulated at 400 Hz, and then printed at different exposure levels. A condition of minimum 400 Hz output from the print was considered to be optimum, where the fill-in of the negative waveforms was being cancelled out in the print.

A variable area soundtrack is fundamentally an oscillographic trace of the original sound waves, having all the area on one side of the trace transparent, and all the area on the other side opaque. Various forms of variable area recordings have been developed, such as unilateral, bilateral and push-pull, but all are designed to vary the light intensity that reaches the photocell – or light-sensitive element – in the sound reproducer, in relation to the original sound waves.

Because of the way images are formed in film materials, complete opacity and transparency are impossible, but high density contrast is essential in obtaining an adequate signal-to-noise ratio. In a good quality variable area recording the film image must be exactly the same size and shape as the optical image by which it was produced.

All film materials diffuse light as it passes through the sensitive emulsion. The effect of diffusion is to spread the exposure through the emulsion in surrounding areas. As a result, the boundary of the film image lacks sharpness, and it may be larger or smaller than the original optical image.

At lower frequencies, where the recorded waveforms are fairly large, image spreading is of little significance. But in the film images corresponding to higher frequencies, the peaks and troughs of the waveforms become distorted. To produce prints with images having the same size and shape as the original optical waveforms, the negative images must be made larger, and the clear portions smaller. Then, in printing, the printer exposure has to be adjusted to cancel out the waveform distortion in the negative. Optimizing negative and print exposure conditions in this way reduces sibilance. The balance density, determined by a cross modulation test procedure, might be expected to give cancellation of as much as 40dB in the 400 Hz output.

Recently there has been greatly increased interest in photographic sound recording. Advances in recording techniques, materials and equipment have made possible high quality stereophonic recording in both 16mm. and 35mm. motion pictures, each channel being recorded in one-half of the normal variable area soundtrack.

With the advent of widescreen pictures, stereophonic sound became very popular. At first the sound was recorded on magnetic tracks, on the edge of the picture film, or a separate synchronously-running magnetic film. The added cost of striping and recording the sound tracks and the multi-channel reproducing equipment gave impetus to the development of improved photographic sound systems.

Distortion Balance Testing Procedures.

A paper in the September 1977 issue of SMPTE Journal, with the title "Distortion Balance Tests for Motion Picture Sound Tracks" by Ralph Wells, formerly of Columbia Pictures Corp. in Hollywood, describes a method

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for calculating optimum print density from a measurement of the percentage distortion in the negative. This means that distortion rather than negative density is the determining factor in the exposure of the sound track in the prints. With this method, production operations can be speeded up and improved considerably.

Distortion caused by image spread, recording slit width and printer contact are second harmonic, increasing both with frequency and amplitude. When the negative distortions are the same amplitudes as the print distortions, they will cancel and give high quality prints.

In the conventional cross modulation test method, a 400 Hz sine wave is generated whenever unbalanced distortion is present. The distortion balance generator developed at Columbia Pictures Corp. makes use of a constant-amplitude high-frequency signal of 80 percent amplitude, pulsed at a 400 Hz rate. The test frequencies can be prerecorded on magnetic tape and spliced or looped to provide a simple test source for making the photographic sound tests.

A distortion balance test can be recorded, printed and measured with a 400 Hz filter in exactly the same way as the conventional cross modulation test, and will give the same results, but a quicker, simpler and more accurate technique, is to make use of percent distortion instead of cancellation. The author describes this method as follows:

"To provide a reference it is assumed that if a high frequency section were to fill-in solid, it would generate a square wave with amplitude equal to one-half the peak-to-peak value of the original sine wave signal. This square wave is our 100 percent distortion reference, and it is easily generated by substituting a 400 Hz square wave having an amplitude which is 50 percent of that of the high frequency sine wave. The square wave is recorded first as a reference, followed by the distortion balance signal. The print is then played back through a 400 Hz filter and the gain adjusted to give a 100 percent output meter reading. Distortion is then read directly as a percentage of this output voltage instead of decibel cancellation".

Illustrations in the paper show how the distortion balance test produces nearly straight parallel lines on a graph where percent distortions are plotted against negative and print densities, and these lines intersect a "zero" distortion line, where the negative and print distortions are balanced.

Variations of this test procedure are described in the paper also, including a coded distortion balance test on the same principle as an aerial navigation system where a pilot can hear a series of Morse code "A's" (dit-dah) when his aircraft is on one side of the radio beam and a series of "N's" (dah-dit) on the other side. On beam, the signal is nulled. This kind of test indicates aurally (without measurement) a density mismatch of about 0.04, corresponding to 1.5 percent distortion.